SHIP = CE^2: REVISITED

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EXTENDED ABSTRACT

Addressing the issue of climate change is a pivotal issue, in particular ensuring that global temperature rises are limited to rising by no more than 2°C above pre-industrial levels by 2100 [1-3]. Nonetheless, there remains an overreliance on fossil fuels within society [3] and; the reducing emissions largely focuses on supply side measures, especially decarbonising the energy sector. One area where significant emission reductions can also be achieved is from within the industrial sector [4-6], where the products and materials we use in society are produced. Here, supply side measures such as *energy* efficiency improvements have stalled in recent years [7, 8], yet there remains significant potential to improve the *material* efficiency of these materials and products once they enter into society [9]. Material efficiency is defined as “providing material services with less material production and processing”[4 p.362]. Options identified by Allwood et al [4] include: 1) reuse of components; 2) reducing yield losses; 3) less raw material for the same service; 4) longer life products and services and 5) upgrading and remanufacturing of products.

In this study the reuse of a steel hull from a ship is used as a case study to explore the CO_2 implications of embedding increased material efficiency measures in the shipbuilding sector, with particular focus on options 1) and 4). The findings are discussed alongside wider technical and non-technical barriers to outline opportunities for the sector and steel industry to progress material efficiency.

Reducing the energy use and greenhouse gas emissions associated with vessel production receives limited attention compared to mitigation measures related to operations and technology. Despite high recycling rates at end of vessel life, where ships are broken and the components cold rolled in places like India and Bangladesh [10, 11] or remetled in places such as Turkey, the current business model for ship building and breaking does not embrace fully material efficiency principles. The policy landscape is shifting however, with the Hong Kong Convention, tabled at the International Maritime Organization, aimed at introducing international regulations on ship recycling [12]. There is also further progress by larger shipping operators such as Maersk, with their materials ‘cradle-to-cradle passport’ to allow for more efficient decommissioning [13].

A life cycle assessment (LCA) approach is used to determine the effectiveness of increased material efficiency to reduce CO_2 emissions. The LCA approach provides CO_2 inventory data for the following life cycle stages: raw material processing, steel plate production, hull manufacture, hull maintenance, breaking and disposal. Assembling this inventory data together provides an approximate emissions profile for the production of a steel hull. To understand the benefits of reuse, a typical cradle-to-grave system is not adequate and instead, the life cycle system boundary is to consider two hulls used over their respective lifetimes. Consequently, the functional unit is two hulls used for duration of 26 years each (52 years total).

For the purpose of the study, 3 scenarios are explored: Business as usual (BAU) case for the

production, use and scrapping of two hulls in series; Scenario 1 – Reusing the hull as a whole between two vessels; Scenario 2 – Reusing the hull as parts (50% of hull 1 reused in hull 2). Figure 1 outlines the generic system boundary for the 3 scenarios studied. The vessel selected is based on commercially available data for a Maersk Line ‘Triple E’ vessel.

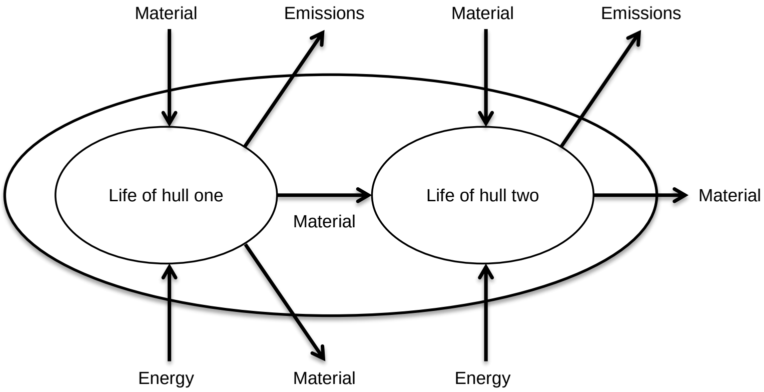

Figure 1: Generic system boundary diagram of material, energy and emissions flow for each scenario

The results from the inventory analysis for the LCA approach are presented in Table 1. When compared to BAU, designing and manufacturing for increased material efficiency via 100% hull reuse provides an emissions reduction of 29% from 221,978t CO_2 to 158,285t CO_2; the 50% reuse option provides a 10% reduction (199,816t CO_2). Nonetheless, there is an assumed increase in maintenance schedules for Scenario 1 and 2 (an increase from 8 to 12 compared to BAU), and therefore the associated CO_2 emissions are higher than the BAU case – (70,381t CO_2 from 51,013t CO_2, an increase of 38%).

Table 1: Total CO2 emissions per functional unit for each scenario

	BAU	**Scenario 1**	**Scenario 2**
Life cycle stage	Tonnes CO_2/functional unit		
Birth 1	68,111	68,111	68,111
Manufacture 1	12,383	12,383	12,383
Maintenance 1	25,506	35,191	35,191
Breaking 1	4,989	0	2,495
Birth 2	68,111	0	34,055
Manufacture 2	12,383	2,421	7,402
Maintenance 2	25,506	35,191	35,191
Breaking 2	4,989	4,989	4,989
Total	221,978	158,285	199,816

Despite these savings there remain barriers with progressing material efficiency. To reduce emissions associated with transportation, material production, ship building and breaking should be co-located where possible – this could ensure consistency during the reuse phase; yet, could also have socio-economic impacts, as current breaking regions are dependent on this industry. From a technical perspective, a vessel would be required to be designed for dismantling and have an operation and maintenance schedule that ensures the value of the steel is retained over its life cycle. From a safety perspective, the cataloguing of material history should be implemented to ensure corrosion and fatigue are recorded and minimised – this requires data on the quality of the steel to be retained and flow between steel producers, ship yards and owners.

This research recommends public and privately funded demonstration projects at a range of scales and markets, to provide investors the business models and confidence that there is retained value in the steel hull when it reaches its end-of-life. Further research would require a whole-systems approach to better inform policy and industry covering technical and financial feasibility; socio-economic and environmental impacts and; regulatory and market assessments.

FOR MORE INFORMATION ON THIS STUDY PLEASE REFER TO THE FORTHCOMING ARTICLE IN MARINE POLICY – *'THE ROLE OF MATERIAL EFFICIENCY TO REDUCE CO_2 EMISSIONS DURING SHIP MANUFACTURE: A LIFE CYCLE APPROACH'.*

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